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The Training Effect of Working Memory Based on Central Executive System Intervention in Older Adults: A Randomized Controlled Study

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Abstract This article aims to investigate the training effect of working memory in older adults. A total of 43 older adults ranging in age from 75 to 95 were recruited to participate in the study. A battery of tests regarding central executive function, working memory, and primary mental ability were administered in the pretest phase. A total of 22 of the older participants were randomly selected as the intervention group. Thirteen days after the pretest, the same tests were administered to all of the participants. The results showed that (1) the differences in the pretest and posttest gains in the task-switching tests were not significant between the intervention group and the control group; (2) the performance of the intervention group on the operation working memory span test and the graphical reasoning test showed a significant improvement after the intervention compared with the control group who did not receive the intervention. We can conclude that the working memory of old adults may be improved by an intervention targeting the central executive system. However, this possibility needs further investigation.

Keywords Central executive system · Working memory · Cognitive intervention · Old adults

Introduction

In 1982, Baltes and Willis proposed that through intervention, the cognitive function of older adults can be improved, and, to a certain extent, the trend of cognitive aging can even be reversed (Baltes et al. 1988; Willis et al. 2006). Meanwhile, cognitive intervention can also improve brain function. Since then, studies have focused on different types of cognitive interventions (Thompson and Foth 2005; Stine-Morrow and Basak 2010). Intervention research in cognitive aging has focused on two major areas: one area is memory intervention based on the strategy usage, such as intervention strategies that target episodic memory (Brehmer et al. 2008; Kliegl et al. 1989; Verhaeghen et al. 1992); the other area focuses on interventions targeting the "core skills," such as working memory, speed of processing, and executive function (Dahlin et al. 2008a, b; Karbach and Kray 2009). When analyzing the gains associated with the intervention, researchers often focus on improvements in the performance of trained tasks within the domain of the intervention (intervention gains), improvements in the performance of non-intervention-related tasks in the same cognitive domain (near transfer), and the effects of the intervention on other cognitive abilities (far transfer) (Li et al. 2008).

Investigators have become increasingly interested in memory, especially episodic memory. Researchers have trained subjects to use different types of memory strategies to investigate the usage of the strategy and the transfer effect (Verhaeghen et al. 1992). However, an increasing number of intervention studies have turned the focus to the "core skills," especially working memory (Li et al. 2008). Studies have shown that there is a significant decline in working memory with aging (Borella et al. 2008; Paxton et al. 2008). Meanwhile, working memory plays a key role in cognitive function (Baddeley 2007; Barrett et al. 2004; Oberauer 2005). Working memory is an important mediating factor of many cognitive functions during aging, and it is essential for processing tasks involving initiative and strategy (Shen et al. 2003). Working memory is related to behaviors that require the storage of stimulus and processing information, such as comprehension abilities,

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complex learning skills, and fluid intelligence (Barrett et al. 2004). Furthermore, it is also an important factor in Alzheimer's disease (Barkley 1997; Carter et al. 1998) and cognitive aging (Craik et al. 1994). Therefore, if older adults can benefit from working memory intervention and transfer the intervention effect to other forms of fluid intelligence, such as reasoning, then this type of intervention may be extremely important for slowing the trend of cognitive aging and preserving daily functions, such as effectively coordinating and searching for information.

The concept of working memory was proposed by Baddley and Hitch in 1974 based on the analysis of short-term memory and has been expanded since then. (Baddeley and Salame 1986; Baddeley et al. 1993, Baddeley and Hitch 1994; Baddeley and Andrade 2000). Working memory is a source-limited memory that stores and processes information temporally. Initially, the structure of working memory proposed by Baddeley is composed of a central executive system, a phonological loop, and a visual spatial sketch pad. However, there are several problems cannot be explained by the three-component model, such as the relation between working memory and long-term memory. Therefore, the researchers modified this model by adding the forth component named episodic buffer into the structure. The episodic buffer is assumed to be capable of storing information in a multidimensional code and controlled by the central executive (Baddeley 2000). What's more, there is clear distinction between working memory executive control and working memory capacity. As is illustrated by the former studies, the central executive is a pure executive attention system which does not have the function of storage (Lu et al. 2008). Initially, working memory interventions were mainly performed in ADHD patients (Barkley 2006). Klingberg et al. (2005) trained seven subjects ranging in age from 7 to 15 with the working memory tasks of the visual spatial sketch pad. The results showed that there was a significant improvement in the Stroop effect and in the scores of a reasoning test, and these improvements were maintained for 3 months (Klingberg et al. 2005).

Based on the previous studies, we can conclude that the aging of working memory follows the principle that the more complex a system is, the earlier it will begin to decline. Therefore, central executive is thought to be the first aging component in working memory system (Chen et al. 2003a, b). Salthouse et al. (2003) found that the aging of the central executive was important for cognitive aging. Chen and Li (2007) investigated the effect of working memory updating and the speed of processing on fluid intelligence with respect to age. In their study, a battery of working memory updating, speed of processing, and fluid intelligence tests were administered to 142 subjects ranging in age from 18 to 85. The researchers used structural equation modeling to analyze the results and found that the working memory updating ability is more important than the speed of processing in cognitive aging.

In view of the fact that the central executive function declines firstly in the system of working memory, and considering that it is important to the aging of other cognitive functions, there have been some efforts aiming to improve working memory using interventions targeting the central executive system. Li et al. (2008) trained 19 young subjects ranging in age from 20 to 30 and 21 old subjects ranging in age from 70 to 80 with the *n* back tasks at two processing levels for a period of 45 days with 15 min of training/day. They found that in the two intervention tasks, both age groups had significant gains, and the old subjects gained more than the young subjects. Meanwhile, there was a significant transfer effect to another *n* back task requiring more spatial information and the number *n* back task, but no significant far transfer effect was found. The measurement after 3 months showed that the retention of the transfer effects by the old subjects was not as good as that of the young subjects, but the scores was still higher than those obtained on the pretests. In 2008, Dahlin et al. trained young and old subjects with information updating tasks for 5 weeks, and the results showed that both the young and old adults exhibited significant gains due to the intervention, and the effects of the intervention were maintained for over 18 months. Meanwhile, the analysis of the transfer effect showed that, as a result of the training, the young subjects improved significantly in another task involving continuous information refreshment (the three-back task), but a similar transfer effect was not observed among the old subjects.

Based on the analysis above, we can find the following problems in the studies of working memory executive system intervention:

1. The intervention methods and cognitive components of previous studies were relatively simple. Most of the studies chose the *n* back task, one single intervention paradigm may result in poor migration effects (Dahlin et al. 2008a, b). Baddeley (1996) believed that the central executive system is not a single, but a separate function. By studying patients with traumatic brain injury, he described the following four central executive functions: coordinating, inhibition, conversion, and refreshing. Engle (2002) proposed the theory of maintaining a target; he believed that the reason that complex breadth tasks and the other cognitive functions are correlated is the independence of these tasks during executive function, namely "executive attention," and not their requirement for short-term storage. Executive attention is the core concept of this theory, which refers to the ability to actively maintain the targets and use this maintenance to inhibit incorrect response trends. With

respect to the four functions of the central executive system, the function of inhibition and attention switching may be a good explanation for the characterization and maintenance of the targets. Based on the preceding discussion, in this research, we chose the functions of inhibition and attention switching to train the working memory executive system of old adults.

2. In previous studies, the intervention methods and materials were consistent or very close with those tasks used in the pretest and posttest. Therefore, the real intervention effect and the practice effect cannot be truly separated.

To solve the problems mentioned above, in this study, we selected an intervention program that included both the functions of inhibition and attention switching, and we avoided any coincidence between the intervention program and the measurement tasks. Additionally, to maintain the ecological validity of this study, we confirmed that the design of the intervention program was in line with the characteristics of older adults. In summary, by performing an intervention in older subjects with the tasks that target the central executive system of the working memory, this study aimed to investigate the training effect of working memory in older adults, including the intervention effects and transfer effects.

Methods

Design

In this study, we chose a 2 × 2 mixed design (measurement time: pretest and posttest; intervention type: intervention group and control group) with measurement time (pretest/posttest) as the within-subject factor and intervention type (intervention group/control group) as the between-subject factor. Before the intervention, a battery of tests regarding the central executive function, working memory, and primary mental ability were administered to all participants. Then, the subjects were randomly assigned to the intervention group or the control group. Thirteen days after the pretest, the same three tests were administered to all participants.

Sample

Forty-three older adults (20 males and 23 females) ranging in age from 75 to 95 years were recruited at the Shanghai South Pier and Shanghai South Pier II nursing homes. Twenty subjects were randomly assigned to the intervention group, and 23 subjects were randomly assigned to the control group. The mean age was 84.5 ± 4.92, and the average number of years of education was 6.90 ± 4.25. The independent sample t test showed that in both age groups, the differences in the mean age and the mean number of years of education between the intervention group and the control group were not significant, $p > .05$.

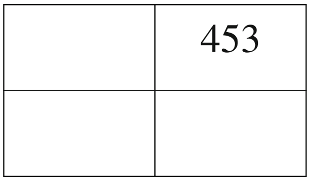

Fig. 1 The mixed task in task-switching test

Measurement

Central Executive System

1. *Task-Switching Test* First of all, the subjects were asked to complete two single tasks, in which they only need to follow one rule to complete the task. According to the previous studies, the single task reflects simple and nearly automatic execution (Orit and Nachshon 2005). In the single tasks, the subjects should determine whether a three-digit number was odd or determine whether the number was >500. There were 30 trials of each task, and the mean reaction time was recorded.

In the mixed task of task-switching test, a 2 × 2 grid was placed in the central part of the screen and there was a three-digit number in one cell of the grid. When the number appeared in the two cells above, the subjects were asked to determine whether this number was odd. When the number appeared in the two cells below, the subjects were asked to determine whether the number was >500. The appearance of stimulus is shown in Fig. 1. There were 96 trials during the test and 16 trials of practice before the formal test.

In the entire task-switching test, half of the trials required the subjects to switch attention between different tasks, which were referred as switching trials (when the number appeared in the cell of the upper left or lower right portions of the grid), while the other half of the trials did not require task-switching, which were referred as repeated trials (when the number appeared in the cell of the upper right or lower left portions of the grid). The subjects' response accuracy and reaction time were recorded. The difference between the reaction time for the trials requiring task-switching and that for the trials that did not require task-switching was recorded as the switching cost, which indicates the cost of task-switching between switching trials and repeated trials. The difference between the reaction time for the switching trials and single-task trials was recorded as the mixing cost, which reflects the global control mechanisms or sustained control process when the executive control functions is in response to the task instructions when the cognitive system is forced to operate under a complex and control demanding situation as compared with the simple execution of a single task (Orit and Nachshon 2005; Koch et al. 2005). These two indicators reflect the individual's ability for planning and switching when facing multiple processing tasks. A higher value of these two indicators indicated less attention switching ability.

2. *Stroop Task* The subjects were shown Chinese characters written in color (e.g., "red" in green), and they were asked to determine the print color of the characters. The stimulations were divided into experimental materials and control materials. The experimental materials were five Chinese characters expressing color information, including "红" (red), "绿" (green), "蓝" (blue), "白" (white), and "黄" (yellow); the control materials included five Chinese characters expressing non-color information. The word frequency and strokes were matched with the experimental material. All the stimulations were presented on a computer. The subjects were asked to press a key to respond. There were 30 trials each with the experimental materials and the control materials, and there were 60 trials in total. The Chinese characters used in the practice before the formal test corresponded to the control material. The response accuracy and time were recorded. The difference in the response time between the experimental material and control material represented the Stroop effect, and a higher value indicated worse individual inhibition ability.

Transfer Effect Tests

Working Memory Span

Operation Span The Operation Span task involved both processing and memory storage components: participants solved simple arithmetic problems (basic addition and subtraction) while trying to remember the answer to each equation. Each equation was printed on a piece of paper. The participants were instructed to perform the calculation in their mind and remember the answer to each question, holding the entire set of answers in their memory until they were instructed to recall them in the same serial order that the equations had been presented. The answer to each equation ranged from 0 to 9. The set size varied from 1 to 9, and it gradually increased. There were three sets of the same size. If the participants could not correctly calculate or recall two of the three sets, the task was ended. If the set size was n when a participant finished, the maximum number of equations the participant could both calculate and recall correctly was $n - 1$. $n - 1$ represented the working memory span for each participant. The equations used in the practice session and the formal experiment were not the same.

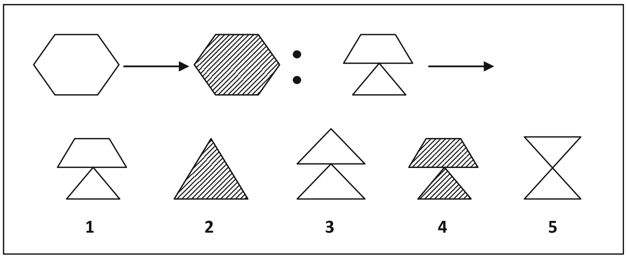

Fig. 2 The figure reasoning test

Figure Reasoning Test

Reasoning is a complex cognitive ability, and it was thought to be the core component of general fluid intelligence (Carroll 1989). A high correlation has been reported between reasoning ability and working memory (Aekerman et al. 2005; Oberauer et al. 2005). Therefore, the figure reasoning test as a representative of the primary mental ability was chosen to explore transfer effects. In this task, the subjects were asked to find the target figure among five alternative choices according to a changing rule between two given figures, as is shown in Fig. 2. The number of correct answers given in 3 min was recorded, and the dependent variable in this test was expressed as the number of correct responses in 1 min.

Intervention Task

1. *Poker Inhibition Task* The subjects were asked to read the suit of one poker card and say "dingdong" (Chinese onomatopoeia) if the suit was a heart. The subjects were required to inhibit their reaction to the suit when the card was a heart.
2. *Poker Switching Task* The subjects were asked to read the digit on a poker card if it was placed near the trainer's head and read the suit of the card if it was placed near trainer's stomach. Thus, the subjects were required to switch their attention between reading the digit and reading the suit.
3. *Poker Switching Task* The subjects were asked to read the suit of a poker card if the card was red and read the digit if it was black. The subjects were required to switch their attention between reading the digit and reading the suit.
4. *Size-Meaning Switching Task* Two Chinese characters "大" (meaning "large") and "小" (meaning "small") in two sizes of font (large and small) were printed on a paper. Some characters were drawn with a line under them while others were not. The subjects were instructed to read the meaning of a character if there was a line under it, and they were asked to indicate the font size (large or small) if there was no line. The

subjects were required to switch their attention between naming and size detection.

5. *Color-Meaning Switching Task* Two Chinese characters “红” (meaning “red”) and “绿” (meaning “green”) were printed in two colors (red and green) on a paper. Some characters were drawn with a line under them, while others were not. The subjects were instructed to read the character if there was a line under it and say the name of the color if there was no line. The subjects were required to switch their attention between naming and color detecting.
6. *Color-Meaning Switching Task II* Chinese characters “红” (meaning “red”), “绿” (meaning “green”), “黄” (meaning “yellow”), and “蓝” (meaning “blue”) were printed in four colors (red, green, yellow, and blue) on a paper. The subjects were instructed to read the character if there was a line under it and say the name of the color of it if there was no line. The subjects were required to switch their attention between naming and color detection.

Research Procedure

Due to health condition, the older group received an intervention for 10 days and 3 min a day. There is a rest of 5 min between the intervention tasks. The intervention was performed according to the following schedule. After each trial of the intervention tasks, the subjects can get the feedback about their performance.

The schedule of the intervention process for the old adults

The first day	Introduced and guided the old subjects to the intervention program and made them familiar with the poker suit
The second and third day	The poker inhibition task
The forth and fifth day	The poker switching task I
The sixth and seventh day	The poker switching task II
The eighth day	The size-meaning switching task
The ninth day	The color-meaning switching task I
The tenth day	The color-meaning switching task II

Results

Some of the older adults could not press the keys on the keyboard because of their poor heath; therefore, the examiners pressed the response keys for them. The response time for the task-switching test and the Stroop test might have been affected because there were differences in the simple reaction time between the old adults and the young examiners. The switching cost, mixing cost, and Stroop effect were calculated by subtraction, which might eliminate the simple reaction time. Therefore, only the variances in the reaction time from two types of responders were considered. The results of the homogeneity of the variances test are shown in Table 1. There was no difference in the variances of the reaction times between the older adults and the young examiners for either the task-switching or the Stroop test.

Training Effects of the Intervention on Central Executive System

Task-Switching Test

The pretest and posttest values for the switching cost and mixing cost of the intervention and control groups are shown in Table 2.

Repeated measure analysis of variance was conducted to determine whether there were differences among the intervention and control groups at the pretest and posttest assessments. The results showed that, for switching cost, the main effect of measurement time was significant, $F(1,42) = 11.61$, $p < .05$. The main effect of intervention type was not significant, $F(1,42) = 0.67$, $p > .05$. The interaction effect was not significant, $F(2,41) = 0.004$, $p > .05$. For mixing cost, the main effect of measurement time was not significant, $F(1,42) = 3.54$, $p > .05$. The main effect of intervention type was not significant, $F(1,42) = 0.077$, $p > .05$. The interaction effect was not significant, $F(2,41) = 0.763$, $p > .05$. Since none of the main effect or the interaction effect for mixing cost was significant, and the scores of mixing cost and switching cost were too different to combine, we will not analyze this part of results further.

Cohen’s d was calculated to evaluate the effect size between the pretests and the posttests of the two groups. As shown in Table 2: for the switching cost, $\mathrm{ES}_{\mathrm{control}} = 0.45$ and $\mathrm{ES}_{\mathrm{training}} = 0.76$. The effect size in the intervention group was greater than that in the control group, which shows that the intervention targeting the central executive system of old adults was effective.

Stroop Test

The pretest and posttest performances on the Stroop test of the intervention and control groups in the old subjects are shown in Table 3.

It can be observed that the Stroop effect did not appear in the pretest, but it did in the posttest. Meanwhile, in the control group, the Stroop effect was more pronounced in the

Table 1 Homogeneity of the variances in the task-switching test and the Stroop test (ms)

	Task-switching test				Stroop test	
	Switching cost of pretest	Switching cost of posttest	Mixing cost of pretest	Mixing cost of posttest	The Stroop effect size of pretest	The Stroop effect size of posttest
Pressed by examiners	2,327,424.85	1,396,013.14	3,190,796.24	1,062,775.42	1,724.98	450.66
Pressed by subjects	1,245,790.82	975,554.93	3,167,260.90	1,111,190.06	2,041.19	901.04
F test (*p* value)	>.05	>.05	>.05	>.05	>.05	>.05

Table 2 Descriptive statistics of the switching cost and mixing cost of pretest and posttest (ms)

	Switching cost		Mixing cost	
	Intervention group	Control group	Intervention group	Control group
Pretest	806.93 ± 1,337.57	1,064.04 ± 1,242.45	471.43 ± 1,399.53	955.58 ± 2,024.16
Posttest	73.11 ± 242.60	471.43 ± 1,399.53	213.82 ± 898.18	660.22 ± 1,152.06
Cohen's *d*	0.76	0.45	0.22	0.18

Table 3 Descriptive statistics of the Stroop effect for the pretest and posttest (ms)

	Intervention group	Control group
Pretest	−358.41 ± 2,293.73	687.91 ± 1,495.29
Posttest	528.23 ± 1,059.30	228.97 ± 270.22

Table 4 Descriptive statistics of the operation span for the pretest and posttest

	Intervention group	Control Group
Pretest	3.60 ± 1.46	3.22 ± 1.41
Posttest	4.50 ± 1.60	3.48 ± 1.41
Cohen's *d*	0.59	0.18

posttest, the opposite of the expected result. A possible explanation for this result may be the decline of visual function in older adults, implying that they may not see the color of the test material clearly, leading to invalid results. Boaz and Schneider (2009) found that the visual acuity of old adults may have an impact on their performance in the Stroop task. On the other hand, it is possible that the subjects did not understand the task requirements, leading to the opposite result. It should be illustrated that the Stroop task is more likely to rely on the educational level since the Stroop effect can only occur when the subjects can tell what the word is. According to our practice, the average educational level of the old subjects in this study (6.9 years) can enable them to understand and perform the tasks in this study. Based on the above analysis, in this study, the Stroop test score was not a valid dependent variable for the older subjects. It will not be analyzed further.

Transfer Effect of Central Executive System Training

Operation Span Test

The pretest and posttest performances of the operation span test for the intervention and control groups of the older subjects are shown in Table 4.

Repeated measures analysis of variance was conducted using the scores for the operation span in older subjects. The main effect of measurement time was significant, $F(1,42) = 9.81$, $p < .05$, but the main effect of intervention type was not significant, $F(1,42) = 2.94$, $p > .05$. The interaction effect was marginally significant, $F(2,41) = 2.97$, $p = .09$. It can be observed from the simple effect analysis that the difference between the pretest and the posttest in the intervention group was significant, $F(1,42) = 11.03, p < .05$, and that it was not significant in the control group, $F(1,42) = 1.07, p > .05$.

Cohen's *d* score was calculated to evaluate the effect size between the pretests and the posttests of the two groups of old subjects. As shown in Table 4, $\text{ES}_{\text{training}} = 0.59$, which was greater than that for the control group, $\text{ES}_{\text{control}} = 0.18$.

Figure Reasoning Test

Next, the transfer of the figure reasoning test intervention was analyzed. The pretest and posttest performances of the figure reasoning test for the intervention and control groups in the old subjects are shown in Table 5.

Table 5 Descriptive statistics of the scores of the inductive reasoning test for the pretest and posttest

	Intervention group	Control group
Pretest	1.23 ± 0.94	0.96 ± 0.80
Posttest	2.14 ± 1.03	1.29 ± 0.76
Cohen's *d*	0.92	0.42

Repeated measures analysis of variance was conducted using the scores of the figure reasoning test in the older subjects. The main effect of measurement time was significant, $F(1,42) = 31.30$, $p < .05$, and the main effect of intervention type was significant, $F(1,42) = 5.07$, $p < .05$. The interaction effect was also significant, $F(2,41) = 6.76$, $p < .05$. The simple effect analysis showed that the difference between the pretest and posttest in the intervention group was significant, $F(1,42) = 30.66$, $p < .05$, and it was also significant in the control group, $F(1,42) = 4.95$, $p < .05$. The difference between pretest and posttest in the intervention group was greater than that in the control group. It can be concluded that there is a significant transfer effect of central executive system intervention in the old group.

To further test the transfer of training, Cohen's *d* score was calculated. As shown in Table 5, $\mathrm{ES}_{\mathrm{control}} = 0.42$ and $\mathrm{ES}_{\mathrm{training}} = 0.92$, and the ES of the intervention group was greater than that of the control group.

Discussion

The Intervention and Transfer Effects of Interventions Targeting the Central Executive System in Old Adults

In this study, we sought to address the question of whether an intervention targeting the central executive system is effective. According to the analysis of data gathered from old adults, we can see that, to some extent, the intervention is effective, especially in the transfer tasks. In the old group, for the task-switching test, the interaction effect of measurement time and intervention type was not significant, but the effect size of the intervention group was greater than that of the control group. Meanwhile, from the analysis of the transfer effect, we can see that the transfer not only to the operation working memory span, but also to the figure reasoning task was significant in the old group.

From the above discussion, we can conclude that for the old adults, the intervention targeting the central executive system is effective. Yet this effect was not evident in the intervention task itself, but rather in the transfer tasks. The following considerations may explain this result.

At first, these test tasks may be difficult for these old adults. In this study, we chose the sample of old adults. On the one hand, their task-switching abilities have significantly declined; on the other hand, it is difficult for them to keep the switching principle in working memory. Even though they can understand the principle of the tests, it is still a great challenge for them to memorize it based on the decline in cognitive function. What's more, the old adults in this study can be classified into the group of old–old adults ($\mathrm{Mean}_{\mathrm{age}} = 84.5$), which means we should be cautious to generalize this findings to other younger aging adults. The difficulty of task-switching tests for old adults may lead to a floor effect. It may be illustrated by analyzing the task: in the task-switching test, the subjects had to coordinate the following cognitive process: (1) detecting the appearance of the stimulus; (2) figuring out the position of the stimulus; (3) determining whether the rule of trial needed to be switched; (4) determining whether the stimulus was odd or larger than 500; and (5) an operative function that coordinates the whole task process. However, according to our study, the working memory capacity of old adults is of 3 or 4 (Peng et al. 2004). The cognitive operations to complete this task may surpass old people's available resource. Therefore, the tests were not sensitive enough to the changes in central executive system function resulting from training, and these tests may not be appropriate to detect a significant intervention effect.

Additionally, the intervention exhibits significant transfer effects on the working memory span and the figure reasoning ability. It is possible that the central executive system function of the old adults was trained successfully, which improved the performance of working memory span test. Engle (2002) believed that the age difference of the complex span task mainly reflects the executive process, but not the storing capacity. He proposed that the correlation between the complex span task and other forms of cognitive ability was the result of the independence of the "executive process," not the need for short-term storage. The old adults were required to remember different principles in the intervention tasks, which were similar to those in complex breadth tasks with respect to the cognitive components. Thus, the performance of working memory span test was improved. What's more, the training may prime a readiness to cope with these kinds of complex tasks, which need processing, storing, cooperating, and switching. This readiness may be generalized. Thus, working memory and reasoning can benefit from it.

What's more, the transfer effect on reasoning ability supports previous research on the role of working memory in reasoning ability aging (Peng et al. 2004). There are two main theories explaining the relationship between working memory and reasoning ability: the theory of mental modeling and the theory of mental logic (Bai et al. 2007). The former assumes that reasoning is the process of building models on the basis of semantic processing. In the reasoning task, the subject has to maintain the additional premise in working memory to consider the other possible conclusions, and thus, reasoning is more difficult. Therefore, the building of the mental model is constrained by the working memory capacity. The latter theory assumes that in the process of reasoning, the working memory capacity will restrain the process of matching rules on the premise of the syntactic structure, using and storing rules and computing the premise and new information. Based on the above discussion, we improved the readiness of both working memory capacity and central executive system, thus improved the performance of reasoning test.

Limitations of the Present Study and the Directions of Future Research

Validity of the test tasks is needed to be considered. In this study, the central executive system function tests cannot detect the true level of ability of the old adults because the task-switching test was difficult for them, which may affect the test results. In future studies, researchers need to choose the tests carefully and perform a pilot study for old–old adults.

The difficulty levels of intervention tasks are needed to match with measure tasks. To adapt the cognitive decline in old adults, we chose relatively simple intervention tasks, while the tests used were quite difficult. It may be one of the reasons why the intervention had no significant effect. In future studies, the difficulty of the intervention task and test task should be matched. The researchers may choose an intervention program with a reasonable level of difficulty and increase the intervention time appropriately.

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